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THE DIVERSITY OF THE GLACIAL PERIOD ON LONG ISLAND.[1]

As POINTED out by Professor Shaler some years ago, the region between, and including, northern New Jersey and Cape Cod is admirably situated for the preservation of the records of the glacial period.[2] The work of Woodworth on the New England islands has brought forth the complexity of the glacial records there, and the results of the last field season on Long Island and Gardiners Island have connected this work with that of Salisbury in New Jersy and given a basis for a tentative correlation with the deposits of the Mississippi valley.

GARDINERS ISLAND.

Gardiners Island, situated between the two eastern flukes of Long Island, presents many of the features shown on Nantucket, Marthas Vineyard, and Block Island. The succession is essentially the same and the correlation evident. It therefore forms a ready point of reference between Long Island, on the one hand, and the New England islands, on the other.

The structure of the island can best be worked out on the northeast shore, where the bluffs are quite high and are kept clean by the constant encroachment of the sea. Here the succession of strata is:

4. Gravelly till (Wisconsin).
3. Interglacial clays and fossiliferous sands.
2. Glacial gravel and bowlders.
1. Black lignitic clay and white and gray to red sand (Cretaceous).

The first three beds are very much folded and the last one deposited irregularly on their eroded folds (Figs. 1 and 2).

1. *Cretaceous.*—The older beds appear only in a few places where they have been brought up by folding. They are commonly black to dark gray clays and very fine sands with consid-

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[1] Published by permission of the director of the United States Geological Survey.

[2] U. S. Geological Survey, *Seventeenth Annual Report* (1896), Part I, p. 957.

erable pyrite and muscovite. They were seen in four places on the northeast shore, and their presence was inferred in as many more by the large springs which occur along the line of parting between this formation and the gravels above. On the east shore the dark-colored older beds were seen at one place in the bluff at the southern end of Tobacco Lot Bay, here likewise associated with a fold. The white clayey sands, which characterize the Cretaceous on Long Island, were seen in one place in the bluff on Bostwick Bay. They show here in a small overturned fold. These beds, in the absence of definite proof of age, are regarded as probably Cretaceous, and are so correlated.

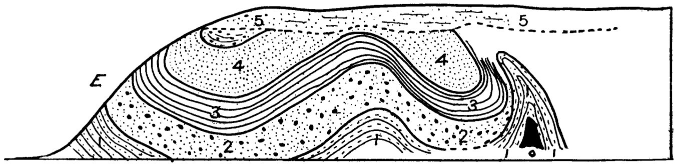

FIG. 1.—Section near middle of northeast shore of Gardiners Island, N. Y. (0) black Cretaceous clay; (1) fine gray micaceous sand (Cretaceous); (2) old glacial gravel; (3) red clay; (4) laminated yellowish-gray silty sand; (5) Wisconsin glacial deposits. Height of section, 60 feet.

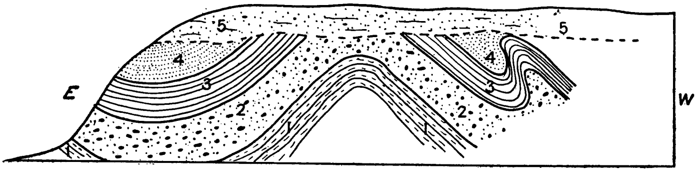

FIG. 2.—Section on west side of the hollow which afforded the figure in sec. 1. About 200 feet farther west. The figures indicate the same beds as in Fig. 1.

2. *Old glacial gravel.*—Overlying the older beds, and involved in the same folds with them, are reddish glacial sand and gravel which, where best exposed, have a thickness of 10 to 15 feet. These beds are for the most part composed of iron-stained quartz, very much disintegrated and in sharp angular pieces. Intermingled with these are many pebbles and bowlders of mica schist, hornblende granite, and granitite, some weighing several thousand pounds. The larger of these compound rocks, while

very much stained with iron, and covered with a coating of pebble-conglomerate, which renders their composition unrecognizable, are not greatly decayed; the smaller ones show very great weathering. When not masked by recent deposits, the lithological character of this bed is quite distinctive.

3. *Red clays and associated beds* (*Sankaty*).—The red clay bed which overlies this gravel is perhaps the most easily recognized and persistent bed on the island. After its stratigraphic position has been definitely fixed in a number of exposures, it becomes a key bed to the whole series. It is a very finely laminated red clay, with occasional sand partings, especially in its upper portion, where it grades into a fine gray to yellowish-gray silty sand. The red clay has a thickness of about 15 feet. Overlying the red clays are very finely laminated gray and yellowish-gray silty sands, which, although somewhat eroded on the north shore, are still 15 feet thick. On the east shore, at Tobacco Point, they apparently grade upward into a peculiar mixture of sandy clay and fossiliferous sands with lens-shaped masses of glacial pebbles in their upper portions. These lenses of glacial gravel are perhaps to be accounted for by floating ice from the approaching glacier which disturbed these beds. The fossiliferous beds are clearly stratigraphically above the red clay, and are involved in the same fold (Fig. 3).

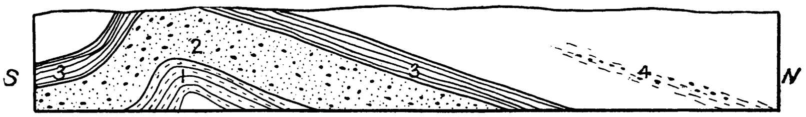

FIG. 3.—Section at Tobacco Point, east side of Gardiners Island, N. Y. (1) Cretaceous; (2) old glacial gravel; (3) red clay; (4) fossil bed with bowlders.

A small collection of fossils from the outcrop on Tobacco Lot Bay, and from another near the western point of the island, have been identified by Dr. William H. Dall as follows:

West point of Gardiners Island:
- Cyprina islandica, Gmelin.
- Crenella arca.
- Modiola sp.

Tobacco Lot Bay:

- Chrysodomus decemcostatus, Say.
- C. pygmaeus, Gould.
- Natica (Lunatia) heros, Say.
- Astarte elliptica, Brown.
- Pecten magellanicus, Gmelin.
- Cyprina islandica, Gmelin.
- Thracia conradi, Coutony.

Dr. Dall remarks: "The material appears to be practically identical from both localities, and to represent the fauna now existing in the gulf of Maine or on the coast north of Cape Cod, a little colder water being indicated than is now found south of the cape." Smith[1] and Merrill[2] have both published lists of fossils which they collected at the Tobacco Lot Bay locality.

These beds present all the characteristics described by Woodworth in the Sankaty beds farther east, and, as already indicated by him, are to be so correlated.[3]

Folding and erosion of Sankaty beds.—Considerable time will be required to completely work out the very complex system of folds developed on this island, but the following points regarding them are of interest. Involving as they do, preglacial, glacial, and interglacial deposits, they are clearly of Pleistocene age, and their irregularity is strongly suggestive of a glacial origin. Near the center of the northeast shore a series of four folds was worked out whose axis is north 20° west. A little farther east, near Eastern Plain Point, there are three or four sharp, partially overturned folds, whose axes are almost due east and west.

Manhasset deposits.—Although the similarity of the Manhasset to the Tisbury beds[4] would lead us to expect them to appear on Gardiners Island on the top of the eroded folds of the older beds, they have not as yet been definitely recognized, but certain thick beds of stratified gravels, whose position could not be satisfactorily determined in the short time that was spent on this island, may prove to be its equivalent. The fact that beds of Manhasset age have been recognized by Mr. M. L. Fuller on Montauk Point and Shelter Island greatly strengthens this supposition. On Shelter Island the beds are, moreover, known to be underlain by fossiliferous clay.

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[1] SANDERSON SMITH, "Notes of a Post-Pliocene Deposit on Gardiners Island, Suffolk County, New York," *Annals of the New York Lyceum of Natural History*, Vol. VIII (1867), pp. 150, 151.

[2] F. J. H. MERRILL, "On the Geology of Long Island," *Annals of the New York Academy of Science*, Vol. III (1886), pp. 354, 355.

[3] J. B. WOODWORTH, *Seventeenth Annual Report* (1896), U. S. Geological Survey, Part I, p. 976.

[4] *Ibid.*, p. 977.

4. *Wisconsin deposits.*— The whole surface of the island is covered with recent morainal deposits. These have so masked the older topography that it is quite morainic in character, though the major topographic features are doubtless due to the distorted older deposits. Where seen in clean sections they are sharply nonconformable to the older deposits. They differ very little from the normal deposits of the same period on Long Island, and have a maximum thickness of about 50 feet.

LONG ISLAND.

For the purpose of this discussion the geologic succession on Long Island may be stated as follows:

- Pre-Pleistocene.
- Pleistocene.
  - Pensauken (glacial).
  - Jameco (glacial).
  - Sankaty (interglacial).
  - Manhasset (glacial).
  - Wisconsin.
    - Ronkonkona moraine.[1]
    - Harborhill moraine.

Pre-Pleistocene.—The pre-Pleistocene formations concern us mainly in that they form the surface on which the Pleistocene beds were deposited. On the western part of the island, about Astoria and Long Island City, on the East River, the crystalline rocks out-crop. Eastward and southward they occur at increasing depths beneath the unconsolidated beds. Such boring records as have been collected in this part of the island indicate a very irregular rock surface sloping southeastward at an average

[1] Name proposed by Mr. M. L. Fuller in manuscript discussion.

rate of about 100 feet per mile. These records are not numerous enough to do more than indicate roughly the general position of the rock surface (Fig. 4), and the extreme irregularity of the rock surface in New York city, where enough records have been collected by Mr. W. H. Hobbs to make its detailed mapping

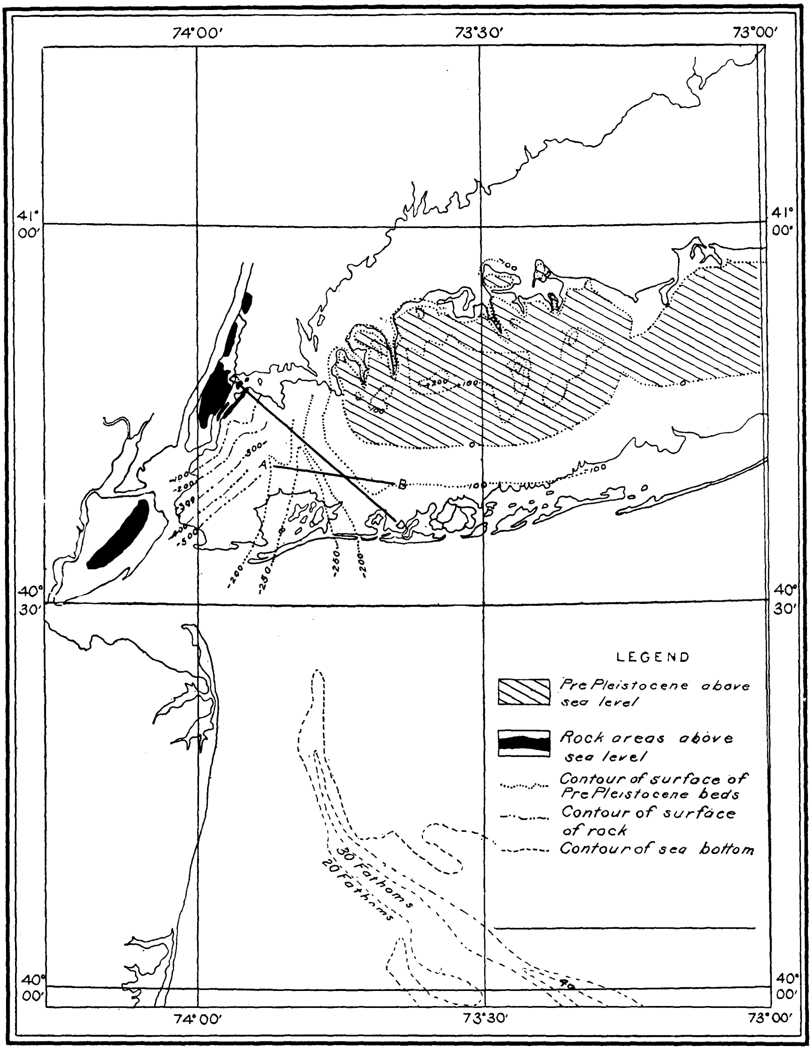
74°00'
73°30'
73°00'
41° 00'
40° 30'
40° 00'
A
B
-100
-200
-300
-500
-250
30 Fathoms
20 Fathoms
LEGEND
Pre Pleistocene above sea level
Rock areas above sea level
Contour of surface of Pre Pleistocene beds
Contour of surface of rock
Contour of sea bottom

FIG. 4. — Sketch map showing the approximate position of the surface of the Pre-Pleistocene formations on Long Island and vicinity.

possible, leads us to believe that a like number of records on Long Island would show a like irregularity.

The pre-Pleistocene unconsolidated beds, represented by sands, gravels, and clay, for the most part Cretaceous, outcrop at many points on the north shore and in the West and Half Hollow Hills. Well sections show that they are present at no great depth under the glacial material in the highest part of the island, and they are now known to form a core about and over which the Pleistocene beds have been deposited. Although involved in sharp folds in many of the bluffs on the north shore, this folding does not appear to extend to any great depth, and the beds in the higher hills are essentially erosion remnants with a small coating of glacial material. On the north shore, between Peacock Point and Lloyds Neck, a number of wells, having a depth ranging from 200 to 500 feet, show a very regular dip of about 65 feet per mile S. 20° E., which contrasts markedly with the crumpled condition of the beds at the surface above them.

The preliminary map (Fig. 4), showing the approximate surface of the pre-Pleistocene unconsolidated beds, as far as they are known from well sections and outcrops, emphasizes two points: (1) the presence of a deep valley passing beneath Jamaica and Jamaica Bay, with a maximum depth exceeding 280 feet below present sea level, which seems to be the logical continuation of the deep channel shown by the soundings of the Coast and Geodetic Survey off New York harbor; and (2) the fact that the older deposits form the greater part of the highest points on the island.

All these beds, so far as known, are Cretaceous, with the exception of a thin bed of "fluffy sand" in the top of the West Hill section, which Mr. G. N. Knapp has referred to the Miocene because of its lithological resemblance to some of the near-by New Jersey beds.

Pensauken.—The oldest of the Pleistocene deposits on Long Island are coarse yellow quartz gravels, which contain a few very much weathered compound crystalline pebbles and cobbles. They are found capping West Hills and underlying the Wisconsin moraine in the Wheatley Hills at no great depth. In the

West Hills they have a thickness of over 35 feet, and reach an altitude of over 325 feet above sea level. These beds are sharply different from the underlying Cretaceous, and are lithologically identical with the Pensauken of New Jersey. Mr. G. N. Knapp, who has spent much time on the Pensauken of that state, has examined the West Hills beds and believes them Pensauken, notwithstanding their rather considerable altitude.[1] Mr. Fuller reports an additional locality on Lloyd's Neck which may belong to these beds. Here the percentage of erratic material is considerably greater, but the state of decay is much the same.

Post-Pensauken erosion interval.—The amount of erosion which belongs to the high-level interval which followed the deposition of this gravel is difficult to determine, but the fact that all the wells that have penetrated the Jameco gravels in the Jamaica-Jamaica Bay valley pass into the Cretaceous without any intervening yellow gravel bed suggests that a portion of the erosion of this valley belongs to this interval.

Jameco gravels.—The borings of the Brooklyn water works and of private parties in the old Jamaica-Jamaica Bay valley have revealed beds of multicolored gravels beneath beds of blue clay. These gravel beds contain only 10 to 20 per cent. of quartz, the remainder being dark-colored shale, red sandstone, trap, granite, and gneiss. The material in these beds varies in size from fine sand to small cobbles. The samples preserved by the Brooklyn water works contain much more erratic material than is generally found in the recent moraine. In the first sample tube[2] examined it was believed that some careless clerk had accidentally inverted it, the upper part of the tube showing yellow gravel, with only a few erratic pebbles, and the lower part, below a thick bed of dark lignitic clay, dark multicolored, highly erratic sands and gravels. The section seemed more correct when reversed, but, as sample after sample was examined, this idea proved incorrect. Records and samples collected the past summer from many wells in the same region have fully confirmed the conclusions from the samples of the Brooklyn water works' test borings. The gravels have a maximum thickness of more than 100 feet near the axis of the old valley, but thin out rapidly in passing eastward, the last wells in which they are known to occur being at Barnums Island and Long Beach. Farther east, the south shore, protected as it was by the Cretaceous upland, received none of these glacial gravels, but still farther east they again appear at Riverhead, here likewise overlain by clay beds. The local name proposed for these beds is from the Jameco pumping station of the Brooklyn water works, which is a few miles south of Jamaica, New York. It was here that borings first revealed these beds.

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[1] Though I have not seen the beds at this locality, I am disposed to doubt their correlation with the Pensauken of New Jersey, unless, indeed, they are the glacial equivalent of the aqueo-glacial Pensauken of New Jersey.—R. D. S.

[2] Samples of the Brooklyn water works are preserved in glass tubes, a miniature reproduction of the strata being attempted.

Blue clay (*Sankaty*).—Overlying these gravels on the south shore are dark-colored clays, having a normal thickness of about 50 feet, and containing considerable lignite and occasional fragments of shells. These beds were laid down as a marginal coast deposit around the nucleus of older material when the land stood about 50 feet higher than today. On the north shore, where erosion has been more active, these beds exist, at present, only as remnants, associated with somewhat similar Cretaceous clays, and, except where brought up by folding, always below sea level. Their differentiation in well sections and small outcrops is, therefore, neither satisfactory nor certain. In no place on the north shore have sections been seen in which this clay bed and the older gravel are clearly shown—a result not to be wondered at when the fragmentary and folded character of these exposures is considered. In the southernmost of the sand pits, just northeast of Plum Point, near Port Washington, beds of laminated gray clay of probable Pleistocene age are exposed in slightly overturned folds. These may be of the Sankaty age.

The greatest thickness of this clay in the Brooklyn water works test borings, 150 feet, is believed to be greater than the true thickness of the deposits of this period. The clay bed is perhaps divisible, the portion below a more or less well-defined sand and fine gravel bed, which separates the section when the clay is of considerable thickness, belonging to the last outwash from the glacier which deposited the Jameco gravels. These greater thicknesses in the clay are generally associated with more or less well-defined valleys in the older gravels (see wells 5, 8, and 18 in Fig. 5), and the wood in the lower portion is rounded, or waterworn in distinction from the compound pieces of lignite found in the upper portion, indicating the true swamp character of the latter deposits. This would leave a thickness of about 50 feet definitely assignable to the Sankaty period in western Long Island—a thickness which is very similar to that found on Gardiner's Island.

Merrill reports the clays at the brickyard west of Greenport very much folded, and they, as well as the clays of Robbins Island, may belong to this age. Similar concretionary clays are found in the high hills between Bridgehampton and Sag Harbor, often very near the surface, and sometimes reaching a height of over 100 feet above sea level—a height doubtless due to folding similar to that shown on Gardiners Island.

The similarity of the stratigraphic position of these beds on Long Island, Gardiners Island, Marthas Vineyard, and Nantucket leaves no doubt of their equivalence to the Sankaty of Woodworth.

Gayhead interval.—There is nothing on Long Island which can clearly be referred to this interval except by inference. While there are many cases of folding on the north shore, the time of the folding is not so clearly fixed as in the small islands to the eastward. Still we feel, from the great similarity of the Pleistocene succession in each case, an assumption that the major folding took place at the same time is not unfounded. The main folding on the north shore occurred before the deposition of the typical Manhasset (Tisbury), as is the case in the New England islands. Some slight folding has doubtless occurred since that time, but it is of small consequence when compared with the older.

Manhasset.—The Manhasset of Woodworth[1] consists of a series of yellow quartz sand and gravel, with an intercalated bowlder bed, and on the north shore lies horizontally on the

[1] J. B. WOODWORTH, *Bulletin of New York State Museum*, No. 48, 1901, Plate I.

truncated folds of the older beds. It differs from the older Jameco in the small amount of erratic material it contains, and from the still older Pensauken in the very slight weathering of the compound pebbles. On the north shore Woodworth has shown that it was deposited as a very level plateau-like plain, reaching a height of over 200 feet. Mr. M. L. Fuller has now proved that it underlies the moraine and occurs south of the moraine in the Half Hollow Hills and the southern end of the West Hills. It is known to underlie the Wisconsin outwash in the plain to the south at an inconsiderable depth and to occur at Far Rockaway. It is in this region that its position is definitely fixed between the Sankaty and Wisconsin (see Fig. 5).

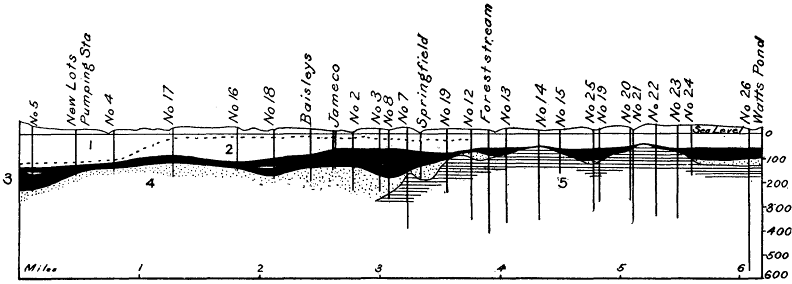

FIG. 5.—Section along the line *ab* of Fig. 4, showing portions of (1) Wisconsin; (2) Manhasset; (3) Sankaty; (4) Jameco; (5) Cretaceous beds, and east side of old valley. Numbers refer to the Brooklyn water-works test wells.

This formation seems to represent waterlaid material when the ice was at no very great distance to the northward. The greater part of it is regarded as the equivalent of the Tisbury of Woodworth for the following reasons: (1) deposition between the Sankaty and Wisconsin; (2) deposition after the main folding of the older beds; (3) marked nonconformity between it and the overlying Wisconsin; (4) similarity of formation; (5) similarity of elevation.

A portion of the folded Manhasset of Woodworth may be referable to the Jameco, but the evidence is not sufficiently clear at present to warrant such a reference.

The Vineyard interval.—As in the New England islands, the Manhasset is separated from the Wisconsin by a period of uplift and subaërial erosion of very considerable extent. The land probably stood somewhat higher than at present. Much erosion occurred on the north shore, but it is hardly believed that the whole of the erosion of the deep re-entrant valleys can be referred to this period.

Wisconsin.—This period is represented on Long Island by two sharply defined terminal moraines and the accompanying ground moraines and outwash plains. The two terminal moraines exhibit some little shifting of the ice lobes, the younger one, as pointed out by Woodworth,[1] crossing the older one near Lake Success. This is quite in accordance with the dual character of the Wisconsin worked out by Leverett[2] in Ohio with its shifting of the ice lobes.

RÉSUMÉ AND CONCLUSIONS.

Having presented briefly such facts as have immediate bearing on the question in hand, the following résumé and statement of conclusions is pertinent. In this the several epochs are treated in ascending order, beginning with the oldest, the scheme of classification shown on p. 766 being followed:

1. The Pensauken has not been recognized on the New England islands, but its outcrop on Long Island near the Jameco gravels makes it possible definitely to refer the "first glacial" of Woodworth to a stage younger than the main body of the extra-

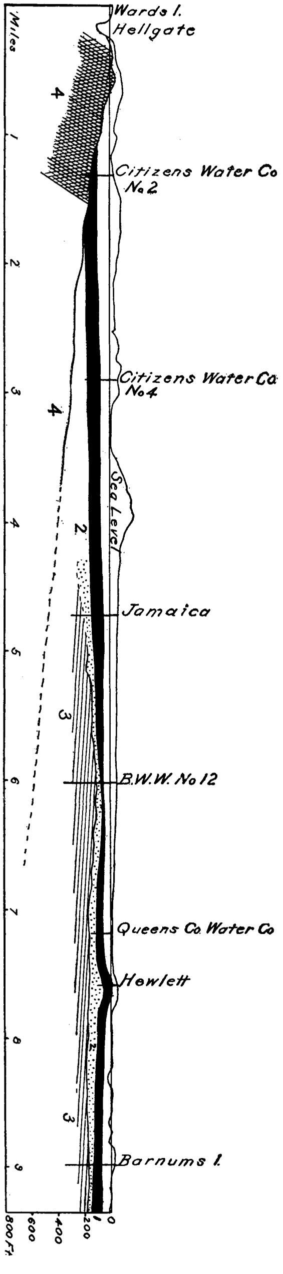

FIG. 6.—Section along the line *cd* of Fig. 4. (1) Sankaty; (2) Jameco; (3) Cretaceous; (4) "Bed Rock."

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[1] *Loc. cit.*, p. 642.

[2] FRANK LEVERETT, *Monograph U. S. Geological Survey*, Vol. XLI (1902), pp. 41, 352, 353.

morainic drift in New Jersey. The deposition of the Pensauken on Long Island indicates submergence of something over 300 feet.

2. In the erosion interval which followed the land stood higher than at present, the absence of Pensauken gravel in the old western Long Island valley indicating that the elevation was something over 250 feet above the present sea level.

3. Following this erosion, the Jameco gravels were laid down in this old valley. These gravels are essentially continuous from the New England islands through Long Island possibly to eastern New Jersey. The ice seems to have about reached the northern part of Long Island and the Jameco gravels to be an outwash from the ice in this position. The very large bowlders at Gardiners Island and at Gayhead indicate that the ice was not far distant at these points.

4. Regarding the relative position of the land during the deposition of the following Sankaty beds we have evidence only in western Long Island, the folding in the other islands preventing any conclusions. On Long Island the land stood 50 feet higher than today, and these beds were laid down as marginal coastal deposits about the older island-like nucleus. The climate, as indicated by the fossils, was not much different from that existing now, and a long period of deglaciation seems indicated.

5. All the evidence which has thus far been collected regarding the greatly contorted folds which involve all the beds between and including the Cretaceous and Sankaty, points strongly to a glacial origin. No evidence of the ice advance besides the folding exists other than the glacial gravels which occur associated with the fossil bed on Gardiners Island and suggest an approach of the ice. The fact that no glacial deposits have been recognized on the mainland which correspond in age to this folding can hardly be regarded as proving that such an advance did not occur. Other ice advances clearly shown on the island have not been recognized on the mainland, the older deposits apparently having become so involved in those of the more recent advances as to make the exact time of their deposi-

tion uncertain. Separated as this is from the preceding glacial epoch by heavy beds of clay and fossiliferous sands, and from that following by marked erosion, this period seems to deserve the rank of an epoch.

6. The exact nature of the erosion in the interval between the folding and the deposition of the Tisbury beds is difficult to determine. That suggested by the outcrops is a decapitation of the folds by wave action, the land standing somewhat lower than today. The nonconformity shown is very marked and forms a ready plane of reference.

7. The Tisbury or Manhasset beds represent glacial outwash when the land stood at least 200 feet lower on Long Island, and 140 feet lower on Marthas Vineyard, than it does today, and the bowlders in the Marthas Vineyard and the bowlder beds in the Long Island deposits perhaps represent the deposits of floating ice.

8. In the Vineyard interval, which separated the Tisbury from the Wisconsin, there was widespread erosion; the land stood somewhat higher than today, and the surface of the preceding deposits was greatly trenched by stream erosion.

9. In the last ice advance the change in the shape of the ice lobes, shown by the crossing of the two outer Wisconsin moraines, suggests the twofold division of the Wisconsin found by Leveret in Ohio.

CORRELATIONS.

The correlation of the Pleistocene succession here shown with that in the Mississippi valley is necessarily more or less tentative, but cerain points are worthy of note: (1) the number of glacial epochs is in each case the same, and (2) the correlation of the Pensauken and extra-morainic drift of New Jersey with the pre-Kansan, or sub-Aftonian, which will follow if these glacial epochs in each case are to be regarded as synonymous, is supported by a growing feeling among Pleistocene geologists that the old extra-moranic drift of New Jersey is rather older than the Kansan; hence the growing tendency to say Kansan or pre-Kansan in speaking of these deposits. These results are remarkably in accord with this idea, and if the oldest and youngest beds of the series are equivalent and there are the same number of epochs, the feeling that the intervening epochs are more or less synonymous must be very strong, and the following correlation suggests itself:

North America	New Jersey	Long Island	Gardiners Island	New England Islands
Pre-Aftonian	Extra-Morainic Drift and Pensauken[1] (Not differentiated)	Pensauken	Wanting	Wanting
Aftonian		Erosion interval unnamed	Not separable from pre-Pleistocene erosion	Not separable from pre-Pleistocene erosion
Kansan		Jameco	Jameco	"First glacial"
Yarmouth		Sankaty	Sankaty	Sankaty
Illinoian		Folding	Folding	Gay Head interval
Sangamon		Erosion interval unnamed	Erosion interval unnamed	
Iowan		Manhasset	Not recognized	Tisbury
Peorian		Vineyard internal		Vineyard interval
Wisconsin Early Late	Wisconsin	Wisconsin Ronkonkoma Harbor Hill	Wisconsin Ronkonkoma	Wisconsin

A. C. VEATCH.

WASHINGTON, D. C.,
October 16, 1903.

[1] I have no adequate reason for regarding the extra-Wisconsin-morainic glacier drift of New Jersey as pre-Aftonian, though, on the other hand, I think this is as probable as any other correlation. Neither is it certain that the extra-Wisconsin-morainic glacier drift of New Jersey is a unit, nor that it is all the time-equivalent of the Pensauken, which is not of glacier origin, though it is believed to be aqueo-glacial. Neither is it certain at the present moment that all which has been regarded as Pensauken can be grouped together as a unit, in the sense of corresponding to a particular glacial epoch. It is a composite formation ranging through a somewhat protracted interval.—R. D. S.